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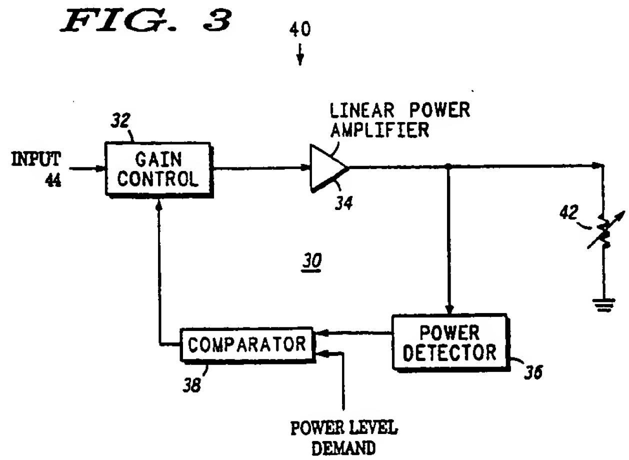
(54) Power management system for a worldwide multiple satellite communications system.

(57) A power management system for a worldwide multiple satellite system having satellites (12, 16, 17) positioned latitudinally in a polar orbiting constellation, each satellite having a plurality of antenna beams, each beam having a given area of coverage or "cell," the total sum of the cells for each satellite forming a larger coverage for the entire satellite (22, 23, 24), the satellites each comprising solar cells and batteries wherein the energy within the batteries is generated by the solar cells and must be efficiently managed. The system comprises an earth based control station (14) which programs each of the satellites within the constellation to supply power to the antenna beams of each satellite at predetermined times to avoid overlapping coverage. Each satellite comprises a voltage regulated linear power amplifier (34) to supply only the power needed for the demand within each of the antenna's cells.

FIG. 3



EP 0 416 462 A2

A portion of a low-orbit satellite constellation system 10 is shown in Figure 1. Such a low-orbit satellite system is described in co-pending EPC Patent Application Serial # 89118458.2, which is hereby incorporated by reference. The view of Fig. 1 is taken along the flight path of satellite 12 as satellite 12 passes over base control station 14. Satellite 12 and adjacent satellites 16 and 17, as well as all other satellites in the constellation, have a substantially polar-to-polar orbit. As the satellites orbit the earth latitudinally, the earth is spinning longitudinally beneath the constellation. Because of the two different rotating trajectories, each satellite in the constellation, at some given time throughout the entire constellation system rotational period, will be overhead the base control station 14.

As satellite 12, for example, passes over base control station 14, satellite 12 transmits information down to base control station 14 relating to the health and status of the satellites power system, circuits, and orbit. Base control station 14 transmits a signal to satellite 12 which programs satellite 12 to operate in a designated manner over a time interval of typically one to two week periods of time. Base control station 14 can also send a signal to satellite 12 which is then relayed to other satellites throughout the constellation, such as satellites 16 and 17 in Fig. 1, when an abnormally large need for satellite communication is required in an otherwise low use area, or when an emergency arises. Such a signal will over-ride programming previously received from base control station 14 by the receiving satellite. Although the above description referenced satellite 12, similar operations apply to all the satellites within the constellation.

Satellite constellation system 10 has several sets of satellites spaced latitudinally around the earth. Due to the polar orbit of the satellites, as each satellite approaches the respective pole, its area of coverage overlaps the coverage area of other satellites approaching the pole. Figure 2 shows the overlap of three different satellites as they approach the north pole over Canada. The areas of coverage 22, 23, and 24 of three different satellites are shown with their individual cells. As seen, heavy overlap exists in overlap area 25. Specific cells, or coverage areas for individual antenna beams, overlap in certain areas. Since only one cell is needed to cover a given area, the present invention allows two of the three overlapping cells to be turned off. The power to the cell's antenna beam is shut off to save power within the satellite.

The significance of the power savings is appreciated when considering the source of power for the satellite and the satellite's orbit. The satellites in the satellite constellation system are powered by solar panels, and some of the energy generated by the solar panels is stored in batteries. As each satellite orbits around the earth in both a latitudinal and longitudinal direction, it experiences periods of time in which it is not exposed to the rays of the sun. During the "dark" periods, the satellite is required to draw energy from the batteries. Depending upon the orbit of the satellite and the demands of the coverage areas, the satellite can use between 200 watts and 1.2 kilowatts of power. Therefore, as satellites overlap coverage, the cells from satellites having the least available stored power would generally be shut off to preserve power for other non-overlapping cells. The energy may also be preserved for high use areas in the satellite's immediate future orbit. Referring again to Fig. 1, assuming satellites 16 and 17 had less energy stored in their batteries than satellite 12, those cells of satellites 16 covering overlap areas 18 and 20 would be shut down. Only the cells of satellite 20 would continue to operate in overlap areas 18 and 20. The commands requiring satellites 16 to shut down are either transmitted to satellites 16 as they pass over base control station 14, or through satellite 12 in cases of exigency. It should be noted that, depending on each satellite's orbit and demand areas, the cell from the satellite having the least energy stored may not necessarily be shut down. Such a determination is made by base control station 14, and either communicated directly to satellite 16, or relayed through the other satellites of the constellation.

Figure 3 shows an additional power control measure of the present invention. Specifically, each satellite in satellite constellation system 10 comprises a demand regulated feed-back circuit 30. By controlling the amount of power used by the satellite through feed-back circuit 30, each satellite can preserve power for periods of use during "dark" periods, or subsequent demand areas.

Feed-back circuit 30 comprises gain control 32, linear power amplifier 34, power detect 36, and comparator 38. Additionally, a power level demand signal 40 is received from a microprocessor on board the satellite. Feed-back circuit 30 is output to a variable load 42, and is also coupled to the batteries of the satellite (not shown) such that gain control 32 receives an input 44 from the batteries.

As the load of variable load 42 increases, a voltage at the output of linear power amplifier 34 decreases. This decrease is detected by power detect 36 which relays the voltage to comparator 38. Comparator 38 compares the voltage level from voltage detect with a minimum threshold received from power level demand 40. If the threshold has been surpassed, comparator 38 transmits a signal to gain control 32 to increase the current supplied to linear power amplifier 34. Similarly, if the load of

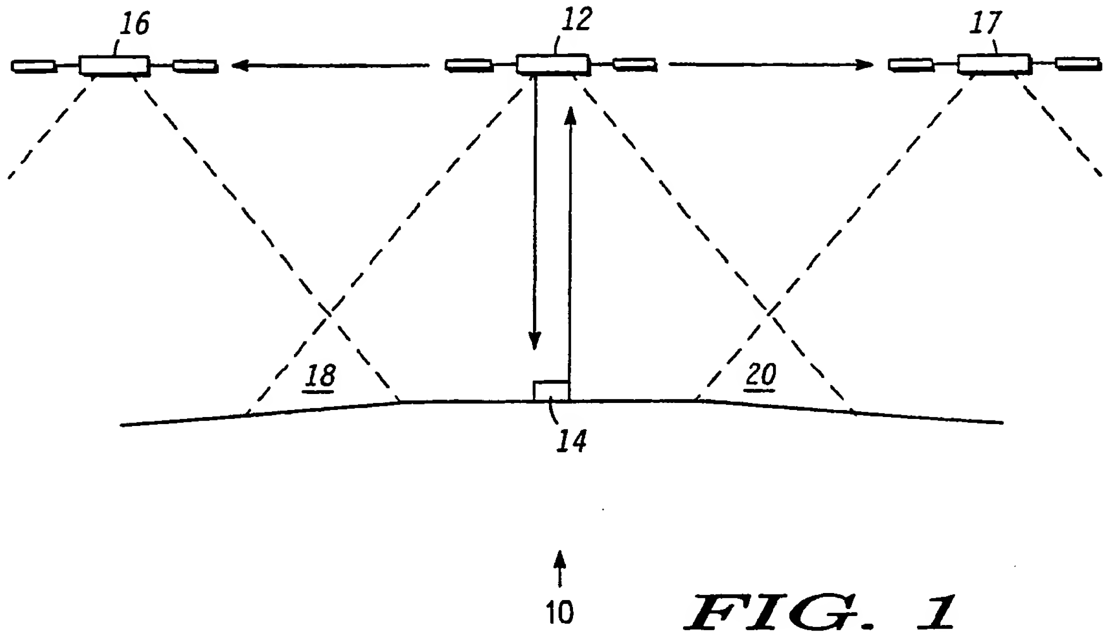

16
12
17
18
20
14
10

FIG. 1

FIG. 3

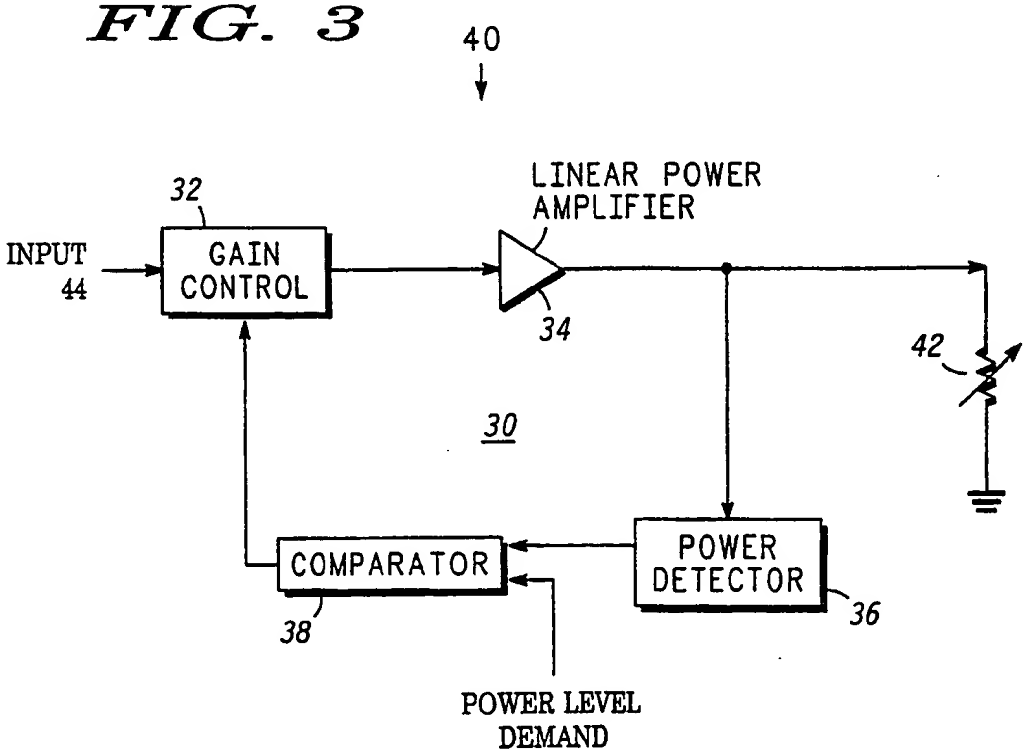

40
LINEAR POWER AMPLIFIER
32
INPUT 44
GAIN CONTROL
34
42
30
COMPARATOR
POWER DETECTOR
38
36
POWER LEVEL DEMAND

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FIG. 3